Soil Water Accumulation under Different Precipitation, Potential Evaporation, and Straw Mulch Conditions

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ABSTRACT

Small precipitation amounts generally have low effectiveness for crop production in semiarid regions. Our objective was to determine potential evaporation (PE; 3, 6, or 12 mm d^{-1}) and straw-mulch (0, 2, or 4 Mg ha^{-1}) rate effects on water accumulation in Pullman (Torrertic Paleustoll, 37% clay) and Randall (Ustic Epiaquerts, 57% clay) soils when small amounts of water (simulated precipitation; 5, 10, or 20 mm) were applied. Water accumulation was affected in order by water-application amount > PE > mulch > soil clay content. Mulching at 2.0 and 4.0 Mg ha^{-1} increased storage efficiency of 5-mm water applications by >60 and 100%, respectively, in both soils when PE was 3 mm d^{-1}. With 5-mm water applications and 6 mm d^{-1} PE, >10% of applied water was stored in mulched soils, but not in bare soils. When PE was 12 mm d^{-1}, little storage from 5-mm applications occurred in bare soils, but 3 to 6% storage occurred when the mulch rate was 4.0 Mg ha^{-1}. To obtain >10% water storage when the PE rate was 12 mm d^{-1}, 10-mm water applications and a 2 Mg ha^{-1} mulch rate were necessary. Evaporation rates were slightly higher for mulched soil than for bare soil in the late stage. Soil clay contents were correlated positively with accumulative evaporation in the late stage. Soil wetting depth increased with increases in mulch rates. Based on this study, straw mulching has potential for increasing soil water storage from small amounts of precipitation.

Water for dryland crop production is supplied by precipitation that is limited and erratic, especially in semiarid or arid regions. Sufficient precipitation seldom is received during a growing season for a crop to produce at its potential (Willis, 1983). Some precipitation events are small, and much of the water evaporates due to the high evaporation potential, thus resulting in little soil water storage. Other events result in runoff and again little water storage. For example, at Bushland, TX, in the southern U.S. Great Plains, an analysis of 60 yr of records showed that precipitation for 69% of the storms was <6.4 mm, and those storms accounted for only ≈18% of total precipitation. In contrast, only 1.4% of the storms provided >51 mm of precipitation and accounted for ≈12% of total precipitation (climatic records, USDA-ARS Conservation and Production Research Laboratory, Bushland, TX). Also, larger storms produced 36 to 41% of runoff during the 1961 to 1979 period (Jones et al., 1985). A similar situation occurs in northwest China and on the Northeast Plain of China, where the spring is droughty and the summer is rainy. In spring, the available soil water supply usually is too low for satisfactory crop seed germination and seedling emergence, which often leads to crop failure. In the summer, however, rainstorms often produce runoff and destroy the cropland. Therefore, for more reliable nonirrigated crop production under such conditions, more of the precipitation must be stored as soil water and efficiently used for crop production (Unger, 1983).

Much research, under both field and laboratory conditions, has shown that use of a surface organic (straw) mulch can result in storing more precipitation water in soil by reducing storm runoff, increasing infiltration, and decreasing evaporation (Bond and Willis, 1969; Unger, 1983; Smika and Unger, 1986; Rao et al., 1998; Schertz and Kemper, 1998). While a straw mulch was effective in most situations for conserving soil water, other research showed that if evaporation is prolonged, a mulch might have little effect (Hanks and Woodruff, 1958), and water from some small precipitation events might not be saved (Russel, 1939). However, there is little information regarding how much water is stored in soil from small precipitation events under different potential evaporation (PE) rates and different straw-mulch rates. Moreover, there is insufficient information regarding soil water accumulation from frequent precipitation events under different PE and surface mulch conditions. Our objective was to determine the effects of potential evaporation and straw-mulch rates on water accumulation in a clay loam soil and a clay soil when small amounts of water (simulated precipitation) are applied.

MATERIALS AND METHODS

The experiment was conducted at the USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX, and involved two soils differing in clay content, three mulch rates, three water application levels, and three PE rates. The soils, both from Bushland, were Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll), which contains 37% clay, 23% sand, and 40% silt, and Randall clay (fine, smectitic, thermic Ustic Epiaquerts), which contains 57% clay, 13% sand, and 30% silt. Randall clay has a clay content and water retention and movement properties similar to those of the black clay soil of the Northeast Plain in China.

The soils were air-dried and sieved (2 mm), then 2900 g were placed into 10.2-cm inside diam. and 30.5-cm long PVC columns that were closed at the bottom. The columns were tapped with a rubber hammer to settle the soil to a height of 28.5 cm. The final bulk density was 1.20 g cm^{-3} for Pullman clay loam and 1.17 g cm^{-3} for Randall clay.

The mulch material was air-dried wheat straw cut into 3- to 5-cm lengths. Mulch rates were 0, 2.0, and 4.0 Mg ha^{-1}, which provided 0, 66, and 94% surface coverage. We applied 5, 10, or 20 mm of distilled water to simulate different amounts of precipitation six times during the experiment with each rate

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Abbreviations: PE, potential evaporation.

of PE for total applications of 30, 60, and 120 mm. The interval between the first two applications was 8 d, while the remaining applications were made at 4-d intervals. The longer initial interval provided an opportunity to better evaluate the PE-rate effect on evaporation rate and accumulative evaporation.

Different PE rates were obtained by changing the number of heat lamps above the soil surface and the length of time that the lamps were on, and by adjusting the temperature of the experimental environment (Table 1). To obtain a constant PE at the 3- and 6-mm rates, the experiment was carried out in a controlled-temperature room, which allowed the establishment of the lower evaporation potentials. For the 12 mm d^{-1} PE rate, the experiment was carried out in a large room that was heated but could not be cooled. The PE rates were determined from measurements of water loss from water-filled columns (same size as for soil-filled columns).

The treatments were replicated three times. The columns were randomly placed in a 30-cm wide band at the outer edge of a 144-cm diam. table that rotated constantly at 1 rpm during each set of determinations at the different rates of PE. This procedure was similar to that used by Unger and Parker (1976). Water accumulation and evaporation data were obtained by weighing the columns at 1-, 2-, or 3-d intervals. Wetting depths were measured when the soil columns were destroyed after the last weighing.

Data were analyzed by the analysis of variance technique (SAS Institute, 1989). When differences were significant at the $P = 0.05$ level of probability, means were separated by Duncan's multiple range test. The coefficients of correlation and regression were obtained from correlation and linear regression analyses.

Table 1. Conditions used to obtain different rates of potential evaporation (PE).

Controlled conditions	PE (mm d^{-1}) 3	6	12
Lamps (150 W each), no.	6	13	20
Time of lamps on per 24-h period, h	6	10	12
Lamp height above soil surface, cm	78.5	78.5	31.5
Average temperature with lamps on, °C	22.2	35.0	37.5
Average temperature with lamps off, °C	15.6	18.3	19.5

RESULTS AND DISCUSSION

Soil Water Accumulation

After six water applications (simulated precipitation events) covering 27 d of evaporation, the amount of water accumulated in soil was affected by mulch rate, water-application amount, and PE. Differences due to the soils generally were small.

As shown in Table 2, use of a mulch increased water accumulation under all PE, water-application amount, and soil clay-content conditions. In most cases, water accumulation increased with increasing mulch rates. For applications of 5 mm per event at any PE, the presence of mulch at 2.0 and 4.0 Mg ha^{-1} resulted in almost doubling and tripling the soil water accumulation compared with that in bare soils. Under the condition of small water applications and high PE, little or no water

Table 2. Water accumulated in soils at the time of the last recording (after six times of water application).

PE†	Application amount	Mulch rate	Pullman clay loam: Amount	Pullman clay loam: % of applied	Randall clay: Amount	Randall clay: % of applied	Difference between soils
mm	mm	Mg ha^{-1}	mm		mm		
3	5	0	5.7a‡	19.1	5.8a	19.4	NS
		2	9.4b	31.2	9.7b	32.2	NS
		4	12.6c	42.0	12.3c	40.9	NS
	10	0	23.5a	39.1	22.3a	37.2	NS
		2	31.8b	53.0	30.9b	51.5	NS
		4	37.3c	62.1	36.4c	60.7	NS
	20	0	74.3a	61.9	72.2a	60.1	NS
		2	86.1b	71.8	85.7b	71.4	NS
		4	94.4c	78.7	93.9c	78.2	NS
6	5	0	2.2a	7.3	1.4a	4.7	NS
		2	4.1b	13.6	3.1b	10.2	NS
		4	5.5c	18.4	5.6c	18.7	NS
	10	0	14.7a	24.5	11.5a	19.2	**
		2	20.9b	34.9	19.4b	32.3	*
		4	27.5c	45.8	26.7c	44.5	NS
	20	0	60.1a	50.1	56.6a	47.1	**
		2	71.5b	59.6	71.9b	59.9	NS
		4	81.6c	68.0	80.9c	67.4	NS
12	5	0	0.4a	1.2	−1.3a	−4.4	**
		2	1.1b	3.6	−0.5b	−1.6	**
		4	1.9c	6.2	0.9c	2.9	**
	10	0	9.3a	15.5	5.1a	8.4	**
		2	12.1b	20.1	7.6b	12.7	**
		4	13.1b	21.8	9.9c	16.5	**
	20	0	40.7a	33.9	38.4a	32.0	NS
		2	45.7ab	38.1	44.7ab	37.2	NS
		4	51.6b	43.0	51.4b	42.8	NS

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† Potential evaporation.
‡ Within columns for each PE and application amount, means followed by the same letter or letters are not significantly different at the 0.05 probability level. NS is not significant. Multiple comparisons based on Duncan's multiple range test.

accumulated in bare soils, but 3 to 6% water accumulation occurred in soils with 4.0 Mg ha^{-1} of mulch.

Based on the total amount accumulated, soil water accumulation was more effective from large than from small water applications for any PE rate and mulch rate for both soils (Table 2). Although the straw mulch provided benefits with all water-application amounts, the largest difference between mulched and bare soils occurred with small application amounts. For example, for 5-mm applications for the 3 mm d^{-1} PE, water accumulation with the 2.0 and 4.0 Mg ha^{-1} mulch treatments was 65 and 121% greater, respectively, than with bare Pullman soil. In contrast, the differences with 20-mm applications were only 16 and 27% for the same soil. The tendencies with other application amounts and for the Randall soil were similar. These results show that use of a straw mulch on soil can improve water conservation for crop production from small precipitation amounts, although the total amount conserved may be small. Even those small amounts, however, usually result in greater soil water storage when crop residues are retained on the soil surface by using no-tillage than when they are incorporated with soil by tillage, even under the generally low precipitation conditions of the southern U.S. Great Plains (Unger and Wiese, 1979; Unger, 1984; Jones and Popham, 1997).

Concerning PE rates, although water accumulation always increased with increases in mulch rates, the effectiveness of mulch rate on water accumulation differed for the different PE rates. For example, for the 3 mm d^{-1} PE rate and 20-mm water applications to the Pullman soil, 62, 72, and 79% of total water applied was accumulated with the 0, 2.0, and 4.0 Mg ha^{-1} mulch treatments, respectively (Table 2). For the 6 mm d^{-1} PE rate, accumulation was 50, 60, and 68% for the respective mulch treatments with the same application amount. In contrast, water accumulation was only 34, 38, and 43% of total water applied with the respective mulch treatments and the same application amount when the PE rate was 12 mm d^{-1}. The mulch treatments were more effective for water accumulation at the lower PE rates (3 and 6 mm d^{-1}) than at high PE rate (12 mm d^{-1}). When the PE rate was 12 mm d^{-1}, not only was total water accumulation lower, but the relative difference between that with the mulched and bare soil treatments was also lower. Linear regression showed that under the 3, 6, and 12 mm d^{-1} PE conditions, each Mg ha^{-1} of mulch resulted in water accumulation increases in Pullman soil of 5.7, 2.8, and 1.3%, respectively, for 5-mm water applications; 5.8, 5.3, and 1.6% for 10-mm applications; and 4.2, 4.5, and 2.3% for 20-mm applications. Similar results were obtained for the Randall soil. These results indicate that use of a straw mulch was more beneficial at the low and middle PE rates with low and middle water-application amounts. Under high PE rates ($\geq$12 mm d^{-1}), water conservation for crop production through use of a straw mulch will be less effective. Fortunately, however, PE rates usually are not >6 mm d^{-1} in most dryland crop production areas such as the southern U.S. Great Plains and northern China (climatic records, Bushland, TX, USA, and Harbin, China). As a result, straw mulching would be fairly effective for conserving water from limited precipitation in such dryland agricultural areas.

Based on this experiment, a 2 Mg ha^{-1} straw mulch would easily result in more than 10% soil water storage from precipitation amounts of 5 mm per storm when PE rates are 3 to 6 mm d^{-1}. For higher PE rates ($\geq$12 mm d^{-1}), 5-mm precipitation events would result in <10% soil water storage, even with a 4 Mg ha^{-1} straw

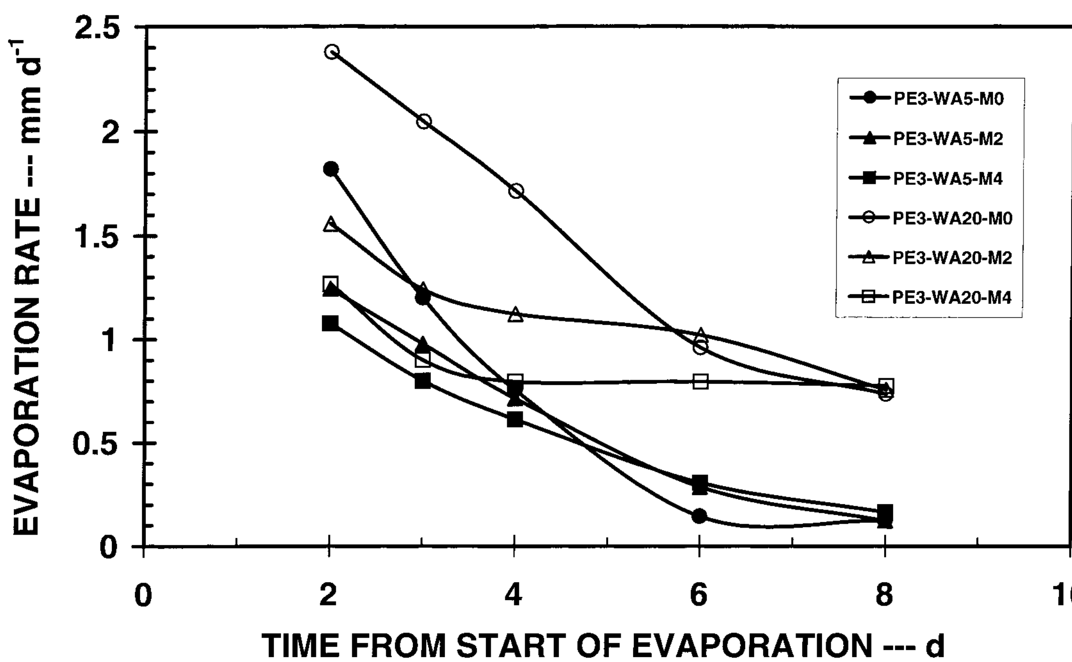

Fig. 1. Soil water evaporation rate as influenced by potential evaporation (PE) at 3 mm d^{-1}, water-application amount (WA at 5 or 20 mm per event), and straw-mulch rate (M at 0, 2, or 4 Mg ha^{-1}).

mulch. To obtain >10% water storage under such high PE rates, 10-mm precipitation amounts and 2.0 Mg ha^{-1} mulch rates would be necessary.

Although the PE rate and precipitation amount strongly affect soil water accumulation when a straw mulch is used, mulching is the only controllable practice in agricultural production. Therefore, mulching will be an effective practice for improving water conservation for dryland crop production.

Soil type did not affect water accumulation significantly in most cases. However, at the high PE rate and with 5- or 10-mm water applications, water accumulation was significantly less in Randall soil with 57% clay than in Pullman soil with 37% clay (Table 2). With low PE rates or high application amounts, differences between the soils in conserving water were not significant.

Soil Water Evaporation

Differences in water accumulation in this experiment resulted from differences in evaporation because water application was controlled and no percolation losses occurred through the columns. Therefore, any other factor that affected water accumulation was through its effect on soil water evaporation.

The highest evaporation rates and greatest differences due to treatments occurred during the initial stage, and most factors affected the evaporation rate in the first few days (Fig. 1 and 2). During the late evaporation stage, the effect of PE and mulch rates became less important, but the water-application-amount effect remained significant.

Among factors affecting evaporation, water-application amount always had a relatively large effect. However, compared with other factors, the application-amount effect varied from the initial to the late stage of evaporation. In the initial stage, when water for evaporation was relatively abundant, the evaporation level depended more on the PE rate, and application amount had only a moderate effect. As evaporation progressed and the effect of other factors became less important, the application-amount effect persisted until the late stage when it became the most important factor. In fact, it almost became the only effective factor in the late stage. The evaporation levels resulting from the different treatments separated into two groups based on two application amounts in the late evaporation stage (Fig. 1 and 2). The accumulative evaporation curves also separated into two groups (Fig. 3), with one increasing because evaporation remained higher due to greater water applications and the other becoming constant because of low evaporation due to low application amounts.

The PE rate was the most important factor affecting the initial evaporation rate. During this period, a high PE rate resulted in a high level of evaporation, and vice versa (Fig. 1 and 2). However, as evaporation progressed, the initially high level of evaporation resulting from the high PE rate declined quickly. In contrast, the initially low level of evaporation with the low PE rate declined slowly. As a result, evaporation with the treatment that resulted in higher initial evaporation rate due to higher PE became lower than for other treatments for which evaporation initially was lower. The high initial evaporation rate resulting from the high PE rate exhausted the soil water supply earlier than where the initial rate was lower. As a result, evaporation quickly became lower with the high initial rate. During the late stage, the level of evaporation depended more on water-application amount and less on PE rate. This may be

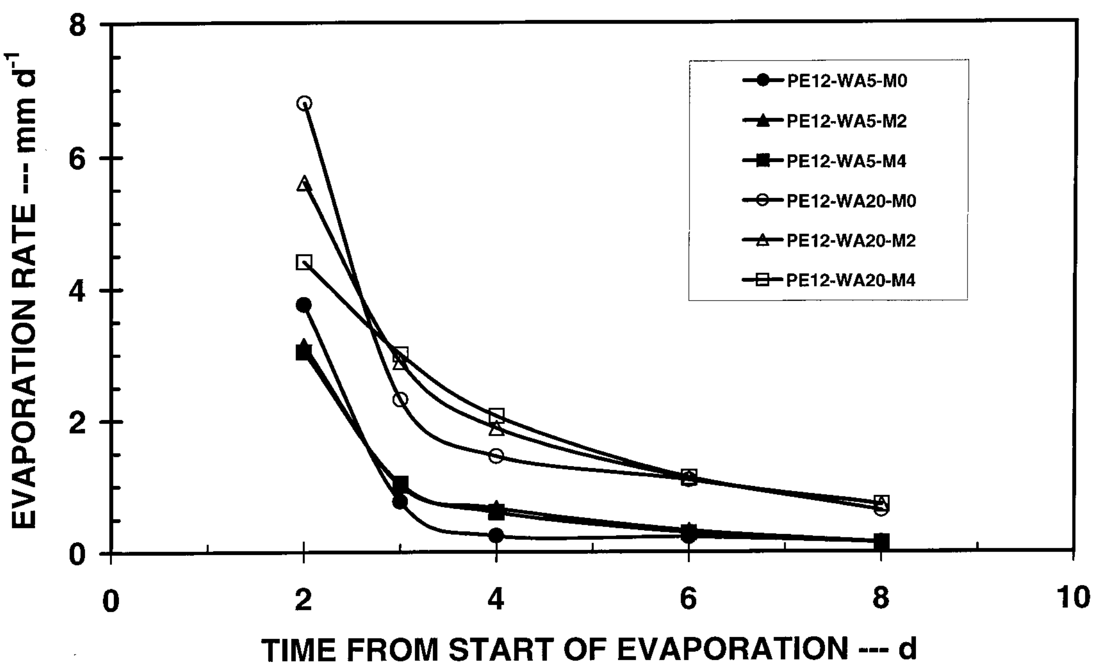

Fig. 2. Soil water evaporation rate as influenced by potential evaporation (PE) at 12 mm d^{-1}, water-application amount (WA at 5 or 20 mm per event), and straw-mulch rate (M at 0, 2, or 4 Mg ha^{-1}).

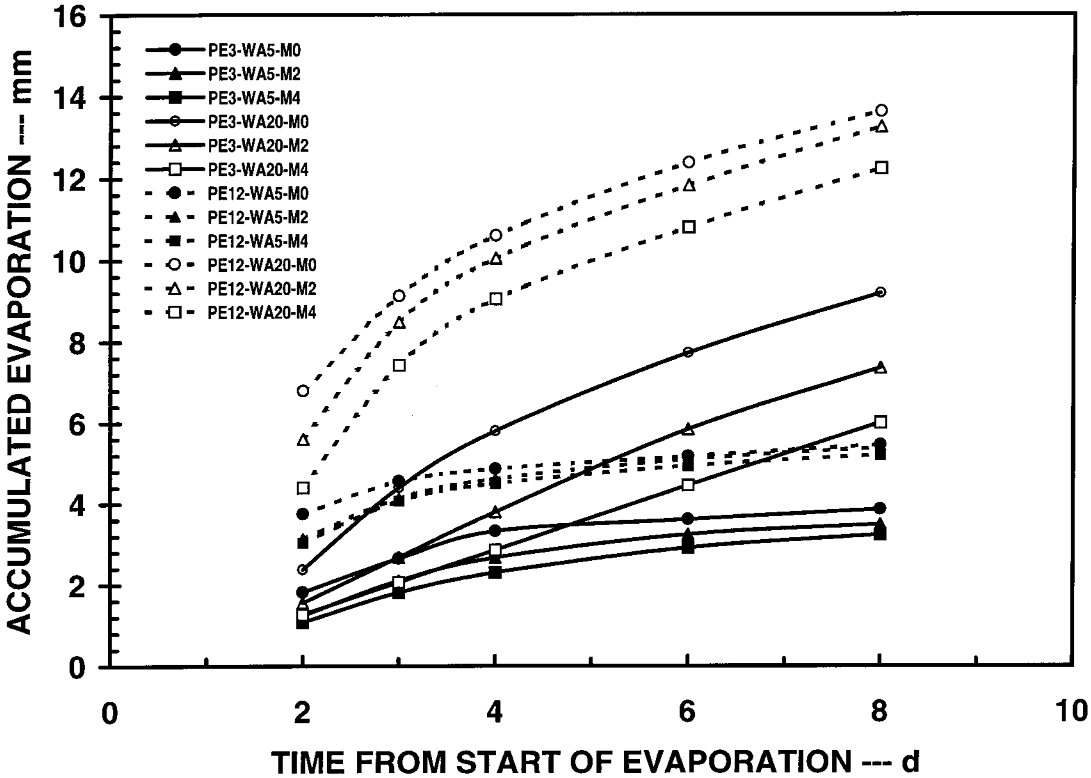

Fig. 3. Accumulative soil water evaporation as influenced by potential evaporation (PE at 3 or 12 mm d^{-1}), water-application amount (WA at 5 or 20 mm per event), and straw-mulch rate (M at 0, 2, or 4 Mg ha^{-1}).

because in the late stage, the PE-rate effect on evaporation was limited by the amount of water available from the soil. Therefore, the PE rate became a less important factor. In contrast, evaporation was greater from soils that contained more water, which resulted in water applications being the most effective factor at this stage. Results similar to these were reported previously (Russel, 1939; Greb et al., 1967; Unger and Parker, 1976).

With a controlled PE rate and water-application amount, initial evaporation always was lower from a mulched soil, as is also shown in Fig. 1 and 2. Because more water was retained in mulched soil (Table 2), evaporation usually was slightly greater from mulched than from bare soil in the late stage. For the first 4 d, mulch amount was negatively correlated with evaporation amount (Table 3). The regression coefficients were negative also. At Day 6 and 8, the mulch factor became positively related to evaporation. This indicates the straw-mulch effect gradually changed from reducing evaporation to supporting evaporation as evaporation progressed (Unger and Parker, 1976). However, these changes due to the mulch factor varied from those for PE rate and water-application amount. Under conditions of low PE rate and higher application amounts, the mulch effect on evaporation reduction persisted for a longer time. As shown in Table 4, the correlation coefficient between evaporation and mulch amount remained negative for 6 d with 3 mm d^{-1} PE and 20-mm water application, and for 3 d with 6 mm d^{-1} PE and 10- or 20-mm water application, but for only 2 d with 12 mm d^{-1} PE and any amount of water application.

Evaporation was much greater in the early than in the late stage with all mulch rates, but it was greater from mulched than from bare soil in the late stage. Even so, accumulative evaporation was less from mulched than from bare soil (Fig. 3), and water accumulation was greater in mulched soils. These results help explain why soil water conservation usually is greater with no-

Table 3. Relationships between evaporation rates and factors affecting the evaporation rates.

Factor	Correlation coefficient 2 d	4 d	6 d	8 d	Regression coefficient 2 d	4 d	6 d	8 d
Mulch	−0.37**	−0.19*	0.05	0.13	−0.33**	−0.05**	0.03	0.04*
Water applic.†	0.29**	0.79**	0.57**	0.72**	0.07**	0.05**	0.11**	0.07**
PE‡	0.87**	0.15**	0.69**	0.36**	0.32**	0.04**	0.19**	0.05**
Clay	0.02	0.09	0.09	0.01	0.01	0.01	0.01**	0.01

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† Water application amount.
‡ Potential evaporation.

Table 4. Correlations between mulch amounts and evaporation rates under different water application amount and PE rate conditions.

PE†	Application amount	Correlation coefficients: Time from start of evaporation (d) 2	3	4	6	7	8
—— mm ——							
3	5	−0.94**	–	−0.81**	0.83**	–	0.41
	10	−0.92**	–	−0.97**	0.30	–	0.79**
	20	−0.94**	–	−0.97**	−0.61**	–	0.22
6	5	−0.83**	0.19	0.40	–	0.50*	–
	10	−0.84**	−0.69**	0.20	–	0.82**	–
	20	−0.90**	−0.78**	0.31	–	0.51*	–
12	5	−0.87**	0.69**	–	0.36	–	0.10
	10	−0.87**	0.23	–	0.57*	–	0.53*
	20	−0.96**	0.66**	–	−0.01	–	0.40

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† Potential evaporation.

tillage, for which all crop residues are retained on the soil surface, than with reduced or clean tillage, which incorporates the residues into the soil (Unger, 1984; Smika and Unger, 1986; Norwood et al., 1990; Norwood, 1992; Jones and Popham, 1997).

Straw mulching benefits soil water conservation for a short period of evaporation, but may not be beneficial for a long evaporation period, as shown by Russel (1939). Based on results shown in Fig. 1, 2, and 3, it is obvious that for a long period of evaporation, accumulative evaporation with different mulch rates will become similar, as reported also by Bond and Willis (1969) and Unger and Parker (1976). However, such a condition does not occur with relatively frequent precipitation, and water conservation is greater with a mulch such as that resulting from the use of a no-tillage cropping system.

Relationships between soil clay content and evaporation rate usually were not significant. However, they became significant at 6 and 8 d of evaporation at the 12 mm d^{-1} PE rate and with 5 and 10 mm of water application. This indicated that soil clay content did affect long-term evaporation.

Depth of Wetting

Water that moves deeply into a soil is less subject to loss during the late stage of evaporation (Greb et al., 1970; Smika and Unger, 1986), thus improving precipitation storage as soil water. The results of this experiment showed that straw-mulch rate, water-application amount, PE rate, and soil type differently affected the wetting depth after six water applications (at 27 d after the first application). These results suggest factors that increase soil water accumulation will increase the depth of water storage in soil.

Water-application amount had the greatest effect on depth of wetting (Table 5). While 5-mm applications only wet the top soil layer (6.1-cm maximum depth), 20-mm applications resulted in wetting the soil to, or close to, the bottom of the column in most cases. When comparing wetting depths with the 5- vs. 10-mm and the 10- vs. 20-mm application amounts, the results clearly show that doubling the water supply more than doubled the wetting depth under any PE rate.

Depth of wetting always decreased with all mulch rates and water-application amounts as the PE rate increased (Table 5). In bare soils with 10-mm applications,

Table 5. Depth of wetting for Pullman and Randall soils resulting from water application amounts, mulch rates, and potential evaporation (PE) rates.

Application amount	Mulch rate	Pullman clay loam at PE rates of 3 mm	6 mm	12 mm	Randall clay at PE rates of 3 mm	6 mm	12 mm	Significance level of the difference between soils at PE rates of 3 mm	6 mm	12 mm
mm	Mg ha^{-1}	cm								
5	0	3.7a^{a}†	3.6a^{a}	3.1a^{a}	3.5a^{a}	2.7a^{a}	1.9a^{b}	NS	NS	*
	2	4.6a^{a}	3.8a^{a}	3.5a^{b}	4.2a^{a}	3.1a^{b}	2.1a^{c}	NS	NS	*
	4	6.1b^{a}	4.8b^{b}	3.4a^{c}	4.6b^{a}	3.9b^{a}	2.5a^{b}	**	NS	NS
10	0	11.6a^{a}	11.7a^{a}	4.7a^{b}	10.2a^{a}	7.0a^{b}	4.3a^{c}	NS	**	NS
	2	15.0b^{a}	12.6a^{b}	9.3b^{c}	13.1b^{a}	9.8b^{b}	6.7b^{c}	*	**	**
	4	15.7b^{a}	14.6b^{a}	8.2b^{b}	13.8b^{a}	11.2b^{b}	6.5b^{c}	*	**	*
20	0	28.8a^{a}	28.8a^{a}	20.0a^{b}	24.9a^{a}	21.8a^{b}	18.9a^{c}	**	**	NS
	2	28.8a^{a}	28.7a^{a}	24.8b^{b}	28.8b^{a}	27.2b^{b}	19.0a^{c}	NS	NS	**
	4	28.8a^{a}	28.6a^{a}	26.2b^{b}	28.8b^{a}	28.7b^{a}	21.9b^{b}	NS	NS	**

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† Within columns for each water application amount, means followed by the same letter are not significantly different at the 0.05 probability level. Within rows for each soil separately, means followed by the same superscript letter are not significantly different at 0.05 probability level. NS is not significant. Multiple comparisons based on Duncan's multiple range test.

the wetting depth with the 12 mm d^{-1} PE rate was <5 cm. With the 3 mm d^{-1} rate, wetting depth was >10 cm in both soils. These results show that with the high PE rate, water from limited water-application amounts did not move deep enough into the soils to prevent it from being lost due to evaporation.

For a given water-application amount and PE rate, the wetting depth was greater with mulched than with bare soil. As a result of the deeper wetting, the water was less subject to subsequent loss by evaporation, which therefore resulted in greater water conservation as shown in the sections pertaining to soil water accumulation and evaporation. With the 2.0 Mg ha^{-1} mulch rate, the wetting depth increased an average of 15, 43, and 11% with 5-, 10-, and 20-mm water-application amounts, respectively. Effectiveness was low with the high application amount because the wetting depth was limited by the length of the column.

In most situations, the wetting depth was greater for the Pullman (less clay) than for the Randall (more clay) soil (Table 5). This is attributed to more rapid water infiltration into the Pullman than into the Randall soil. Undoubtedly, this is one of the reasons why water accumulation was slightly greater in the Pullman soil (Table 2).

SUMMARY AND CONCLUSIONS

Soil water evaporation and accumulation are governed by many factors, including precipitation amount, PE rate, and soil type. In most cases, precipitation amount and PE rate are the determining factors, and soil type is less important. Under practical crop-production conditions, PE rate, precipitation amount, and soil type are not controllable; however, a mulch such as wheat straw on the soil surface is an easily applied practice. Our data show that mulches are beneficial for controlling evaporation and conserving water by decreasing the initial evaporation rates and increasing the depth of water movement into the soil. As a result, use of the straw mulch increased soil water storage and the effectiveness of small amounts of applied water. This suggests that a straw mulch on the soil surface can be used to increase soil water accumulation from the numerous small precipitation events under the normal PE conditions in semiarid regions such as the southern U.S. Great Plains and the Northeast Plain in China.

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